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THE PRODUCTIVITY GAP BETWEEN CANADIAN AND U.S. FIRMS

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THE PRODUCTIVITY GAP BETWEEN CANADIAN AND U.S. FIRMS

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ABSTRACT

Canada's productivity performance in the manufacturing sector has deteriorated compared to that of the United States since 1985 on the basis of both aggregate and industry analyses. The purpose of this paper is to investigate the productivity gap between Canadian and U.S. firms and its underlying factors since 1985. The firm-level data are constructed from the Compustat and Compact Disclosure data bases, supplemented by industry data from Statistics Canada, the U.S. Department of Commerce, and Jorgenson's capital, labour, energy and material (KLEM) data base. We employ a Cobb-Douglas production function to analyse both labour and total factor productivity (TFP) gaps in manufacturing; mining; transportation, communications and utilities (TCU); trade; and services. Our findings indicate that the TFP performance of Canadian firms relative to that of U.S. firms deteriorated from the 1985–88 period to the 1989–92 period in all five broad sectors and that only the mining sector fully recovered in the 1993–95 period. Over the 1993–95 period, Canada lagged behind the United States in TFP in all five sectors, with the gap ranging from 4 per cent in mining to 30 per cent in manufacturing. To explain the TFP gap and its widening over the sample period, we consider differences in labour quality, R&D, firm size, capacity utilization, returns to scale and industrial structure. As important factors contributing to the gap in manufacturing, our results identify labour quality, R&D and capacity utilization, together with an unfavourable industrial structure; in mining the results identify labour quality, R&D and returns to scale; and in TCU they identify labour quality. These factors were also responsible for the widening TFP gap in all sectors except mining.

INTRODUCTION

Productivity performance is a main focus of virtually every country's policy agenda because it reflects the overall efficiency of the economy and directly affects a country's living standards. Given its importance, there is genuine concern among policy makers and researchers about Canada's poor productivity performance. A study by Statistics Canada (1996) reveals that the total factor productivity (TFP) level declined by 0.6 per cent per year in the Canadian manufacturing sector over the 1985–92 period, while in the same period its average annual growth rate was 1.0 per cent in the U.S. manufacturing sector. In fact, for each of the 15 manufacturing industries examined in this study, the Canadian industry's TFP growth lagged behind that of its U.S. counterpart over this period.

The goal of this paper is to measure the productivity gap between Canadian and U.S. firms, and to investigate why Canada's productivity performance has deteriorated compared to that of the United States since 1985. The paper compares productivity levels between firms in five broad sectors in the two countries since that date. To do this it uses firm-level data from the Compustat and Compact Disclosure data bases, supplemented by industry data from Statistics Canada, the U.S. Department of Commerce, and Jorgenson's capital, labour, energy and material (KLEM) data base. The five broad sectors examined are manufacturing; mining; transportation, communications and utilities (TCU); retail and wholesale (trade); and services. We then consider differences in labour quality, research and development (R&D), capacity utilization, firm size and returns to scale as possible explanations for the gap and the deterioration in each sector. In addition, we explore the difference in industrial structure for manufacturing.

This paper is unique in four respects. First, it uses firm-level data instead of the more commonly used aggregate and industry data. Ultimately, firms produce goods and services and compete against one another. They therefore constitute the appropriate unit of analysis. Second, our study compares the productivity performance of Canadian and U.S. firms in the post-1985 period, whereas most earlier empirical studies focussed on productivity performance in the 1970s and 1980s. Third, instead of focussing on growth rates (as do most other empirical studies), we compare both labour and total factor productivity levels between Canadian and U.S. firms. Finally, we investigate the underlying causes of the productivity gap and why it has widened over time.

The main conclusions drawn from this study are the following:

- All five broad Canadian sectors were more intermediate goods–intensive than their U.S. counterparts in the 1993–95 period. Canada's higher intermediate goods intensity was responsible for its relatively higher gross output–based labour productivity (LP) levels. After accounting for the intermediate input-labour ratio, Canadian firms' value added–based labour productivity levels were comparable to or lower than their U.S. counterparts, except in mining, in the 1985–88 period.

- Relatively lower value added–based labour productivity levels among Canadian firms were attributed to their relatively lower TFP levels and not to their capital-labour ratios. In fact, their capital-labour ratios were higher than those of U.S. firms, except in TCU, in the 1985–92 period.

- The TFP performance of Canadian firms relative to that of U.S. firms deteriorated from the 1985–88 period to the 1989–92 period in all five broad sectors, with some recovery in the 1993–95 period in all sectors except TCU. Over the 1993–95 period, Canada's TFP level was lower than that of the United States in all five sectors, with the gap ranging from 4 per cent in mining to 30 per cent in manufacturing.

- Canada's manufacturing sector was more concentrated in less productive industries than was the U.S. manufacturing sector. Differences in the composition of manufacturing industries accounted for more than 25 per cent of the TFP gap in manufacturing between the two countries.

- Labour quality, R&D and capacity utilization were responsible for Canada's productivity gaps in manufacturing, accounting for more than 69 per cent of the structure-adjusted TFP gap (based on the U.S. industrial structure). Labour quality, R&D and returns to scale were responsible for the gap in mining in the 1989–95 period, fully accounting for the TFP gap in this period. Labour quality was responsible for the TFP gap in TCU, accounting for more than 30 per cent of the TFP gap in this sector. However, these factors were not responsible for the productivity gaps in trade and services. Difference in firm size accounted for only a small portion of the TFP gap; this result suggests that the factor was not important for the TFP gaps.

- Labour quality, R&D, capacity utilization, firm size and returns to scale together were responsible for the widening TFP gap between 1985–88 and 1993–95 in all sectors except mining; they explained from 6 per cent of the widened gap in manufacturing to 95 per cent in trade.

In the next section of this paper, we briefly review the empirical literature on productivity. In the section entitled "Empirical Framework," we introduce the model for productivity comparisons. In "Empirical Analysis," we describe the data used and present the estimated results. On the basis of the estimated results, we calculate both labour and total factor productivity gaps between Canadian and U.S. firms. After showing that there was a productivity gap between Canadian and U.S. firms and that productivity performance in Canada deteriorated compared to that in the United States from 1985 to 1995, we discuss the underlying factors behind the gap and the deterioration. The last section concludes the paper.

LITERATURE REVIEW

Productivity is analysed perhaps more than any other subject in economics because of its importance to our standard of living and the complexity of the issues involved. Given the vast literature on the subject, it is beyond the scope of this paper to review all of it. We therefore restrict ourselves to reviewing only relevant empirical papers dealing with productivity. There are three broad classes of empirical studies on productivity. The first class analyses cross-country productivity differences on the basis of aggregate data at the country level. The second class relies on industry data to compare industry productivity levels and growth rates. The last class relies on firm-level data to understand productivity performance.

Country-level data provide evidence that productivity in the industrialized countries has tended to converge since the Second World War; see, e.g., Baumol (1986) and Dowrick and Nguyen (1989). Nevertheless, evidence of productivity convergence based on industry data is not very strong. For instance, Costello (1993) finds that there is a stronger correlation in productivity growth across industries within one country than across countries within one industry. Bernard and Jones (1996*a*, *b*) reinforce this finding as their analyses suggest an absence of productivity convergence in manufacturing for 14 countries of the Organization for Economic Co-operation and Development (OECD) during the 1970–86 period. They find, however, productivity convergence in other sectors, such as services. Their findings suggest that each country may be facing a unique technology shock. Thus, technology transfer or productivity spillover from one country to another is not automatic. It is not surprising, then, that Canada has lagged behind the United States in productivity performance and that the gap has been increasing since the 1980s, as mentioned in the introduction. Most empirical studies show that Canada's productivity performance was relatively poor compared to that of other developed countries.[1] For instance, Englander and Gurney (1994*b*) show that Canada's TFP growth lagged behind that of all other OECD countries, except Greece, in the 1980–90 period on the basis of aggregate data.

Many industry analyses reach similar conclusions. Denny et al. (1992) investigate relative TFP growth and levels in major manufacturing industries of Canada, Japan and the United States. They find that only three Canadian industries (lumber, paper and fabricated metals) were more efficient than their U.S. counterparts in the 1983–85 period, although 7 of the 12 Canadian industries showed an improvement in their TFP levels relative to those of their U.S. counterparts from the 1974–76 period to the 1983–85 period. Rao and Lemprière (1992*a*) show that many U.S. manufacturing industries' TFP growth rebounded in the 1980–88 period after the 1974–79 slowdown, while Canadian industries faced greater difficulty. They then compare labour productivity growth between Canada and the United States for non-manufacturing industries.[2] During the 1961–86 period, Canada's labour productivity growth was significantly higher than that of the United States in transportation, storage and communications; construction; mining; and utilities. In a similar vein, De Jong (1996) compares labour productivity levels in Canada and the United States using unit value ratios. In 1990, Canada's labour productivity levels were lower than those of the United States in all 20 manufacturing industries except tobacco. Furthermore, over the 1979–90 period, the U.S.–Canada labour productivity gap widened in all manufacturing industries except tobacco, wood products, furniture and fixtures, basic and fabricated metals, and electrical machinery and equipment. Similarly, Pilat (1996*a*, *b*) compares industry labour productivity at the sectoral level on the basis of industry-specific purchasing power parities (PPPs). In 1993, all major Canadian manufacturing industries had lower labour productivity levels than their U.S. counterparts, with the exception of base metal products.

All the studies mentioned here relied on aggregate data to measure productivity growth and levels. One exception is that of Keay (1997). He uses 39 Canadian and U.S. firms to assess TFP growth rates and levels in nine industries since the early 1900s. He finds that Canadian firms were more productive than their U.S. counterparts in paper mills, sugar refineries and wineries, and less productive in cotton textile. The study, however, suffers from two weaknesses. First, the number of firms may be too small to accurately reflect industry productivity performance. Second, Keay uses industry wages and material costs in calculating firms' productivity performance. Therefore, his estimates may simply reflect differences in Canada–U.S. industry data but not the productivity gap between Canadian and U.S. firms.

The studies we have mentioned focussed on measuring productivity, but there are many empirical studies that also focussed on finding the determinants of productivity growth. Rao and Lemprière (1992*b*) find that energy price shocks, the exchange rate, R&D effort and industrial structure contributed to the widening of the manufacturing labour productivity gap between Canada and the United States in the post-1973 period. Englander and Gurney (1994*a*) use aggregate cross-country data to investigate the determinants of productivity growth. They find that education and R&D improve productivity performance; however, they do not find large positive externalities associated with physical investment or large returns from infrastructure. Van Ark and Pilat (1993) consider differences in capital intensity, labour force qualifications and industrial structure in explaining differences in the labour productivity levels of manufacturing industries in Germany, Japan and the United States on the basis of unit value ratios. They find that these factors were not very important in explaining the labour productivity gap in 1987.

Pilat (1996*a*) argues that the degree of competition and the growth of R&D stocks appear to be positively related to productivity growth. In recent studies, Gera, Gu and Lee (1998*a, b, c*) investigate the underlying factors behind productivity growth in Canada. They conclude that information technology (IT) investments, international R&D spillovers embodied in IT imports, and foreign direct investment (FDI) were positively related to productivity growth. In addition, they also find that technical progress in Canada was embodied in capital stock, primarily in machinery and equipment.

There are now several firm-based studies that shed further light on the determinants of productivity growth. Li (1997) assesses the effects of China's economic reform on the performance of the country's 272 state enterprises. He finds that the allocation of property rights and incentives has yielded marked improvements in TFP growth. Indeed, on the basis of a sample of 23 international airlines over the 1973–83 period, Ehrlich et al. (1996) find that state ownership lowered productivity growth in the long run. Nickell (1996) reaches the same conclusion as Pilat (1996*a*) on the basis of his analysis of 640 U.K. firms. He shows that competition contributed positively to TFP growth. Baily and Gersbach (1995) show more clearly the importance of competition on productivity; they state, "The greater the exposure of an industry to best-practice methods, the closer it is to best-practice productivity." Griliches and Mairesse (1991), Hall and Mairesse (1995) and Mairesse and Hall (1996) all stress the importance of the contribution of R&D to productivity growth on the basis of their analyses of U.S. and French firms.

In addition, on the basis of firm-level analyses, information technology and effective management of human resources appear to be important for productivity growth. Brynjolfsson and Hitt (1994) and Lehr and Lichtenberg (1997) find that U.S. firms that invested more in computers and information technology tended to have faster productivity growth. Ichniowski and Shaw (1995) study the behaviour of 35 U.S. steel firms during the 1991–93 period to determine the implications of human resource management practices for productivity performance. They show that innovative work practices that emphasize teamwork, flexibility, incentive pay and training result in higher productivity performance.

In summary, both economy-wide and industry analyses appear to show a widening Canada–U.S. productivity gap. Past empirical studies suggest that differences in R&D, IT investments, labour quality, degree of competition and the effectiveness of human resource management practices may have played an important role in productivity growth. We also consider some of these variables to explain the widening productivity gap between Canadian and U.S. firms.

EMPIRICAL FRAMEWORK

We assume that each firm's production activity is characterized by the following Cobb-Douglas production function[3]:

(1) $$Y = AK^{\alpha_K} L^{\alpha_L} M^{\alpha_M} ,$$

where Y is gross output, A is the efficiency coefficient,[4] K is capital input, L is labour input and M is intermediate input. α_K, α_L and α_M are the elasticities of output with respect to K, L and M.

In our empirical analysis, we extend the basic model to explore some factors that may affect productivity. On the basis of data available, in this paper we consider four factors: labour quality, R&D, firm size and capacity utilization. These factors will be discussed in detail in the section on "Productivity Determinants." We use Z to denote these factors and specify the efficiency coefficient, A, as a function of Z — that is, $A(Z)$. We also use industry and period (1985–88, 1989–92 and 1993–95) dummies to capture productivity performance differences across industries and over time.[5] After incorporating these considerations, we derive from equation (1) the firm gross-output labour productivity function for each broad sector. Taking manufacturing, for example, the gross-output labour productivity function is:

(2) $$\begin{aligned} \ln(Y/L) = & \sum_{j=1}^{19} \left[(\alpha_{1j} P_1 + \alpha_{2j} P_2 + \alpha_{3j} P_3) I_j \right] \\ & + \alpha_K \ln(K/L) + \alpha_M \ln(M/L) + (\alpha_K + \alpha_L + \alpha_M - 1) \ln L \\ & + \alpha_Q \ln Q + \alpha_R \ln R + \alpha_U \ln U + \alpha_{S_2} S_2 + \alpha_{S_3} S_3 , \end{aligned}$$

where P_i is a period dummy for period i; I_j is an industry dummy for industry j; Q denotes labour quality; R denotes the R&D factor; U denotes capacity utilization; and S_2 and S_3 are firm-size dummies for medium and large firms.

Gross-output labour productivity is determined by capital intensity (K/L), intermediate goods intensity (M/L), returns to scale, and the exogenous variables affecting production efficiency. The unexplained portion or the residual is given by the constant, which is different for each industry and period.

In order to compare TFP between Canada and the United States, we assume that the elasticities (the slope coefficients) between the two countries are the same as in the index number approach.[6] However, our data show that this assumption does not hold, at least for our sample period. To overcome this problem, we assume that each elasticity takes the average value of the two countries (Denny et al.,1992; Jorgenson and Nishimizu, 1978).[7] Under this assumption, comparisons can be made between the countries.[8] We therefore estimate the firm labour productivity function separately for each country and then take the average value of each estimated parameter:

(3) $$\bar{\hat{\alpha}}_j = 1/2(\hat{\alpha}_j^{CAN} + \hat{\alpha}_j^{US}) , j = K, L, M, Z_i.$$

Note, however, that there is no need to estimate the production function separately if the number of observations from each country is about the same. In this paper, the number of observations is much larger for the United States, resulting in a biased estimated coefficient if the production function is not estimated separately. In Appendix A, we discuss this matter in greater detail.

On the basis of production function (2) with the estimated parameters from equation (3), we are able to compare firm average productivity differences between the two countries for each sector. To reflect differences in firm size, we calculate the weighted firm average productivity for each sector of each country by assigning each firm a weight that equals its gross output share of the sector. For instance, we calculate the weighted average of the TFP levels of the manufacturing sector for both Canada and the United States, and the difference between the weighted TFP averages is the TFP gap in manufacturing between Canada and the United States. To quantify each factor's effect on the productivity gap, we use the following expression for the logarithmic gross output–based labour productivity gap between the two countries in the first sub-period:

$$\begin{aligned} GLPG &= \overline{\Delta \ln(Y/L)} \\ &= \hat{\alpha}_D + \bar{\hat{\alpha}}_K \overline{\Delta \ln(K/L)} + \bar{\hat{\alpha}}_M \overline{\Delta \ln(M/L)} \\ &\quad + (\bar{\hat{\alpha}}_K + \bar{\hat{\alpha}}_L + \bar{\hat{\alpha}}_M - 1)\overline{\Delta \ln L} + \sum_i \bar{\hat{\alpha}}_{Z_i} \overline{\Delta \ln Z_i}, \end{aligned} \tag{4}$$

where $\hat{\alpha}_D = \overline{\Delta \ln(Y/L)} - \bar{\hat{\alpha}}_K \overline{\Delta \ln(K/L)} - \bar{\hat{\alpha}}_M \overline{\Delta \ln(M/L)} - (\bar{\hat{\alpha}}_K + \bar{\hat{\alpha}}_L + \bar{\hat{\alpha}}_M - 1)\overline{\Delta \ln L} - \sum_i \bar{\hat{\alpha}}_{Z_i} \overline{\Delta \ln Z_i}$;

$\overline{\Delta \ln X} = \overline{\ln X}^{CAN} - \overline{\ln X}^{US}$; and $X = K/L, M/L, L, Z_i$. $\overline{\ln X}^{CAN}$ and $\overline{\ln X}^{US}$ denote the weighted firm average logarithmic value of *X* in Canada and the United States in the first period.

After removing the effects of intermediate goods, the logarithmic value-added labour productivity gap between the two countries in the first sub-period is:

$$VLPG = \hat{\alpha}_D + \bar{\hat{\alpha}}_K \overline{\Delta \ln(K/L)} + (\bar{\hat{\alpha}}_K + \bar{\hat{\alpha}}_L + \bar{\hat{\alpha}}_M - 1)\overline{\Delta \ln L} + \sum_i \bar{\hat{\alpha}}_{Z_i} \overline{\Delta \ln Z_i}. \tag{5}$$

Finally, we remove the effects of the capital-labour ratio to obtain the logarithmic TFP gap between the two countries in the first sub-period:

$$TFPG = \hat{\alpha}_D + (\bar{\hat{\alpha}}_K + \bar{\hat{\alpha}}_L + \bar{\hat{\alpha}}_M - 1)\overline{\Delta \ln L} + \sum_i \bar{\hat{\alpha}}_{Z_i} \overline{\Delta \ln Z_i}. \tag{6}$$

The logarithmic TFP gap is decomposed into three terms. The first term is the unexplained or residual component that cannot be explained by the exogenous variables, *Z*. The second component is the returns to scale component,[9] and the last component is the component explained by those factors (*Z*) considered in our regression analysis. If there were no TFP gap between the two countries, the sum of all these terms would be zero.

The equations used to estimate the gaps in the second and third sub-periods are the same as in the first sub-period except that the first sub-period value of each variable is replaced by its corresponding value in the period of interest.

EMPIRICAL ANALYSIS

In this section, we present empirical results comparing both TFP and labour productivity levels between Canadian and U.S. firms. We first briefly describe the data set used for the empirical analysis.

Data

Both U.S. and Canadian firm data are extracted from the Compustat data base. This is supplemented with Canadian firm data from the Compact Disclosure/Canada data base since the Compustat data base contains only a small number of Canadian firms. Firms that have data on sales, assets, property, plant and equipment (PPE), and number of employees are selected. A firm is defined as Canadian if it is incorporated in Canada, and as a U.S. company if it is incorporated in the United States. Thus, we group firms according to their location instead of ownership. A detailed description of data construction is presented in Appendix B.

Our sample contains 5 829 observations for Canada and 38 878 observations for the United States over the 1985–95 period, based on 2 364 Canadian firms and 5 647 U.S. firms as shown in Table 1. Because of firm turnover and missing information, only 105 Canadian firms and 1 873 U.S. firms have complete data for the entire period. All other firms lack data for at least one year; some of these are new companies.

All U.S. and most Canadian firms are publicly traded companies listed on the New York Stock Exchange, the American Stock Exchange, NASDAQ or the Toronto Stock Exchange. Other Canadian firms are either public utilities or private companies which are not publicly traded. Table 2 shows that both Canadian and U.S. firms cover more than 60 per cent of the gross output for manufacturing and TCU, 31 per cent for trade and 17 per cent for mining. The coverage ratios are smallest for services. Both Canadian and U.S. firms cover less than 18 per cent of the gross output in their respective countries' services sector. Accordingly, the results for the services sector should be interpreted with caution.

These firms are initially classified into 26 industries on the basis of the industry code given in the data bases for each firm (Standard Industrial Classification, or SIC).[10] These firms are then re-allocated into five broad categories of sectors since the number of firms in each of the 26 industries is too small for empirical analysis. The five broad sectors are manufacturing, mining, TCU, trade and services. Table 1 lists the number of observations and firms by sector. The manufacturing sector has the most observations and the largest number of firms for both countries.

The firm-level data are then deflated by corresponding 26-industry deflators from Statistics Canada, the U.S. Department of Commerce and Jorgenson's KLEM data set to construct real output and input data.[11] Canada's real output and input variables are converted into U.S. currency using Pilat's (1996*b*) industry purchasing power parities for manufacturing industries or the OECD's (1993) aggregate expenditure–based PPPs for the other sectors.

Table 1
Number of Observations and Firms by Industry

	Manufacturing		Mining		TCU[a]		Trade		Services		Total	
	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
1985	133	1 308	52	86	53	348	30	308	21	273	289	2 323
1986	160	1 428	52	90	60	373	36	352	25	348	333	2 591
1987	165	1 583	51	96	57	393	42	396	31	392	346	2 860
1988	170	1 668	55	101	46	395	53	416	31	402	355	2 982
1989	194	1 732	54	115	53	407	55	432	32	427	388	3 113
1990	219	1 805	71	135	67	411	68	448	41	467	466	3 266
1991	241	1 929	77	138	67	439	105	494	39	531	529	3 531
1992	542	2 100	179	143	125	464	287	556	123	608	1 256	3 871
1993	260	2 367	122	161	93	507	108	636	61	696	644	4 367
1994	251	2 553	129	177	77	535	82	699	66	790	605	4 754
1995	268	2 772	123	186	79	576	79	760	69	926	618	5 220
Total	2 603	21 245	965	1 428	777	4 848	945	5 497	539	5 860	5 829	38 878
Number of firms	1 019	2 915	337	236	227	620	503	806	278	1 070	2 364	5 647

[a] TCU stands for transportation, communications and utilities.

Table 2
Coverage Ratios

Year	Percentage of Total Sample Gross Output to Total Country Gross Output									
	Manufacturing		Mining		TCU[a]		Trade		Services	
	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
1985	64.5	64.6	30.1	17.5	92.7	78.7	34.0	40.7	3.9	10.9
1986	60.0	64.7	36.8	24.5	83.7	77.0	32.7	42.4	5.1	11.6
1987	61.6	68.0	26.4	25.8	81.4	74.7	32.4	42.0	6.5	12.7
1988	62.5	71.4	38.2	31.1	70.0	74.8	31.0	43.0	4.9	12.5
1989	65.4	72.8	36.1	31.8	59.9	75.9	45.1	45.7	4.7	11.6
1990	64.4	77.8	46.0	31.8	68.5	75.8	40.4	46.5	5.6	11.7
1991	62.4	77.7	42.5	25.9	73.1	79.3	45.0	48.9	4.3	11.9
1992	75.0	78.3	62.9	25.0	75.0	79.2	85.9	51.1	9.5	12.1
1993	67.9	78.1	47.8	26.1	63.1	83.4	70.3	54.2	8.5	12.9
1994	65.5	80.1	46.9	32.0	67.4	81.6	66.2	56.4	8.3	14.6
1995	61.1	88.2	43.0	33.5	69.7	87.8	68.0	59.0	6.8	17.7

[a] TCU stands for transportation, communications and utilities.

There are a number of caveats associated with our data set. First, the data set is not complete since the cost of goods sold, labour-related cost and/or R&D cost are missing in some years for some firms.[12] In this case, firms take the corresponding industry average (i.e., the average for 1 of the 26 industries) of cost of goods sold scaled by gross output, labour-related cost scaled by number of employees, and R&D cost scaled by sales. These industry averages are multiplied by the corresponding firm gross output, number of employees or sales to approximate the missing firm data.

Second, because of cross-ownership among firms in our data base, some of them are counted twice. However, this problem of overlapping is expected to have a minimal effect on our results since our regression analysis is based on a large sample of firms.

Third, firms are labelled as Canadian or U.S. according to where they are incorporated. This may not reflect their actual operations since multinationals are often incorporated in one country but have their operations in others. For instance, Northern Telecom is incorporated in Canada but has operations abroad, including in the United States, Asia and Europe. However, this bias is not likely to be serious since most firms have their major operations in the country where they are incorporated.

Finally, the data set is very unbalanced. The average observations per firm are 2.47 for Canada and 6.88 for the United States. Because of this feature, we are unable to test for autocorrelation with the unbalanced sample. However, the evidence from a small longitudinal sample extracted from the unbalanced sample, which is discussed in the section entitled "Estimation of the Productivity Gap," suggests that autocorrelation may not be a significant problem for the purpose of this study.

Productivity Determinants

In this section, we consider four factors to explain the productivity gap: labour quality, R&D, firm size and capacity utilization. These factors are selected on the basis of their availability. In the section entitled "Explanation of the TFP Gap," we discuss the industrial structure and its contribution to the productivity gap between the two countries.

Labour quality and R&D are two common factors considered in productivity analysis. Labour quality is positively associated with productivity since higher-quality workers are more effective in raising productivity by working with machines and other workers. In this paper, labour quality is measured by real labour compensation (PPP-based) because of the lack of other measurements, such as the educational attainment of workers.[13] This proxy has been chosen because of the strong correlation between labor compensation and educational attainment of workers; see Murphy, Riddell and Romer (1997).

Expenditures on R&D often lead to innovation and advanced technology, which result in productivity improvement; see Griliches (1986).[14] In this paper, R&D is measured by real R&D expenditures (PPP-based) divided by the weighted average of capital and labour, that is, $R = RD/L^{\theta} K^{1-\theta}$, where RD denotes real R&D expenditures and θ denotes the average value of value-added labour shares in Canada and the United States at the 26-industry level.[15]

We also consider capacity utilization to account for the business cycle of an economy. Firm size is introduced to differentiate the innovative capacity of large firms from that of small firms, and to capture size-related residuals that are not captured by other variables explored in this paper. Size differences can have two opposing effects on productivity: Large firms tend to have access to a larger pool of technology and their scale has a positive impact on productivity. On the other hand, these larger firms tend to be equipped with older capital, which may not be as productive as more recent vintages. The impact of size on productivity, therefore, can only be validated by empirical analysis. To capture the size effect, we divide firms into three groups according to their size, with the reference group being a small group in which each firm's capital is no greater than US$30 million (PPP-based).[16] The next size is represented by a dummy variable, S_2, equal to 1 for a group where each firm's capital is greater than US$30 million (PPP-based) but less than US$150 million (PPP-based) and to 0 otherwise. S_3 equals 1 for a group where each firm's capital is greater than US$150 million (PPP-based) and to 0 otherwise.

As discussed earlier, we also introduce industry and period dummies to capture productivity differences across industries and over time in each sector.

Estimation of the Productivity Gap

The estimation results of equation (2) for each country are reported in Table 3.[17] The results indicate that the exogenous variable Z played a significant role in influencing TFP. As expected, the coefficient of the labour quality variable was statistically significant and had the expected sign. The R&D variable was positively and significantly related to productivity in all sectors in both countries, except in the U.S. trade sector. The low values of coefficients associated with R&D and the insignificance in trade are not surprising since the role played by R&D to improve productivity in this sector is very limited. The effect of capacity utilization on productivity varied, depending on sector and country. It had a positive and significant impact in manufacturing, mining and TCU for the United States, and in trade for both countries. The effect of firm size on productivity varied, also depending on sector and country. For Canada, large manufacturing firms appeared to be less productive, while medium and large mining firms were more productive. For the United States, medium manufacturing firms tended to be productive while large mining and trade firms and medium services firms were less productive. Firm size had no effect on productivity in TCU in both countries. Although the production function in all sectors in both countries was very close to constant returns to scale, different returns to scale occurred in different sectors in each country, as shown by the estimation results corresponding to the coefficient $\alpha_L + \alpha_K + \alpha_L - 1$ in Table 3. For Canada, TCU and trade were characterized by decreasing returns to scale, mining and services by constant returns to scale, and manufacturing by increasing returns to scale.[18] For the United States, manufacturing, mining and TCU were characterized by increasing returns to scale, trade by decreasing returns to scale, and services by constant returns to scale.

From Table 3, we calculate the averages of the estimated slopes between the two countries. These averages are then used to calculate labour productivity and TFP gaps for the five broad sectors, as shown in Table 4.

All five of Canada's broad sectors were more intermediate goods–intensive than their U.S. counterparts in the 1993–95 period. Higher intermediate goods intensity in Canada was responsible for the country's relatively higher gross output–based labour productivity levels. After accounting for the intermediate input-labour ratio, Canadian firms' value added–based labour productivity levels were comparable to or lower than those of their U.S. counterparts, except in mining in the 1993–95 period. In addition, Canadian firms' value added–based labour productivity relative to that of U.S. firms declined in the 1989–92 period compared to the 1985–88 period in all sectors, and only the mining sector had fully recovered in the 1993–95 period. For instance, the value added–based relative labour productivity in Canadian manufacturing declined from 82.1 in the 1985–88 period to 69.9 in the 1989–92 period, and recovered to 75.7 in the 1993–95 period. This finding is consistent with that of Rao and Lemprière (1992*b*). They determine that Canada's manufacturing value-added labour productivity level relative to that of the United States was 81 in 1985 and 71 in 1990.

Table 3
Independent Estimation Results of Equation (2) for Canada and the United States[a]

Industry	Manufacturing		Mining		TCU[b]		Trade		Services	
Coefficient	**Canada**	**U.S.**	**Canada**	**U.S.**	**Canada**	**U.S.**	**Canada**	**U.S.**	**Canada**	**U.S.**
α_K	0.123*	0.104*	0.135*	0.424*	0.129*	0.169*	0.030*	0.090*	0.141*	0.109*
	(12.6)	(22.0)	(7.6)	(23.7)	(9.1)	(26.8)	(3.4)	(16.8)	(6.5)	(15.2)
α_M	0.578*	0.334*	0.588*	0.314*	0.466*	0.379*	0.801*	0.637*	0.586*	0.440*
	(64.1)	(92.1)	(33.6)	(22.0)	(36.3)	(67.4)	(86.4)	(161.9)	(31.3)	(61.7)
$\alpha_L + \alpha_K + \alpha_M - 1$	0.016*	0.038*	0.017	0.061*	-0.029*	0.014*	-0.024*	-0.019*	0.007	0.005
	(2.2)	(12.6)	(0.9)	(4.3)	(-2.6)	(3.4)	(-3.6)	(-5.3)	(0.5)	(0.9)
α_Q	0.136*	0.223*	0.358*	0.376*	0.452*	0.274*	0.183*	0.419*	0.150*	0.370*
	(11.2)	(11.2)	(6.4)	(5.2)	(9.0)	(11.2)	(8.4)	(16.1)	(4.2)	(14.2)
α_R	0.046*	0.131*	0.032*	0.145*	0.049*	0.094*	0.005*	0.000	0.083*	0.048*
	(11.3)	(54.4)	(5.2)	(14.2)	(6.7)	(20.6)	(2.1)	(0.5)	(7.0)	(20.6)
α_U	0.531	0.425*	0.635	2.428*	0.880	0.522**	2.286*	0.755*	1.162	0.336
	(1.3)	(2.2)	(1.1)	(3.5)	(1.5)	(1.8)	(5.2)	(3.4)	(1.1)	(0.8)
α_{S_2}	-0.034	0.026*	0.288*	-0.020	0.014	0.026	0.001	-0.017	-0.117	-0.052**
	(-1.2)	(2.1)	(4.8)	(-0.4)	(0.3)	(1.3)	(0.0)	(-1.2)	(-1.4)	(-1.8)
α_{S_3}	-0.064**	0.003	0.262*	-0.145*	0.051	-0.001	0.038	-0.043*	-0.135	0.008
	(-1.7)	(0.2)	(3.1)	(-2.0)	(0.8)	(-0.1)	(0.9)	(-2.2)	(-1.2)	(0.2)
N	2 603	21 245	965	1 428	777	4 848	945	5 497	539	5 860
R-Square	0.77	0.53	0.81	0.73	0.82	0.78	0.93	0.91	0.78	0.55

[a] The constant and its related sector and period dummies are not reported. The *t*-ratio is in parentheses.
[b] TCU stands for transportation, communications and utilities.
* Significance at 5% level.
** Significance at 10% level.

Table 4
Productivity Level in Canada Relative to the United States[a]

	U.S. = 100														
	Manufacturing			Mining			TCU[b]			Trade			Services		
	85–88	89–92	93–95	85–88	89–92	93–95	85–88	89–92	93–95	85–88	89–92	93–95	85–88	89–92	93–95
Gross output LP	108.2	97.5	101.4	79.4	113.8	129.8	91.2	80.0	81.8	135.3	119.7	114.6	85.6	105.7	124.8
Value-added LP	82.1	69.9	75.7	102.0	99.8	111.3	92.9	80.0	80.0	87.0	71.2	78.9	100.4	80.4	89.2
TFP	78.3	66.1	69.8	93.9	87.0	96.3	93.6	81.1	77.0	86.1	71.0	77.4	99.3	79.6	84.0

[a] Based on the averages of estimated coefficients in Table 3, equation (4) is used to calculate the logarithmic difference between Canadian and U.S. firms' gross output–based labour productivity (LP). The exponent of the resulting number is taken to calculate Canada's gross-output labour productivity level relative to that of the United States. Similarly, value added–based labour productivity and TFP levels are calculated in the same manner based on equations (5) and (6).

[b] TCU stands for transportation, communications and utilities.

Part of the differences in value added–based relative labour productivity levels can be explained by differences in capital intensity between Canadian and U.S. firms. Once differences in capital intensity are adjusted, the resulting relative productivity levels (TFP levels) became lower for all sectors except TCU in the first two sub-periods. This is because Canadian firms were more capital-intensive than their U.S. counterparts, especially in manufacturing and mining. As in the case of value added–based relative labour productivity levels, Canadian firms' relative TFP levels declined in the 1989–92 period compared to those in the 1985–88 period in all sectors, and only the mining sector had fully recovered in the 1993–95 period.[19] Thus the TFP gaps had widened in all sectors except mining between 1985–88 and 1993–95. In the last period (1993–95), Canada lagged behind the United States in TFP in all five sectors, with the gap ranging from 4 per cent in mining to 30 per cent in manufacturing. This suggests that Canadian firms' capital intensity had not changed much relative to their U.S. counterparts, at least not enough to close the widened gap in value added–based labour productivity.

To see the robustness of our estimation, we also estimate the productivity gap using a longitudinal sample extracted from the unbalanced sample.[20] The evidence from the smaller sample shows that correcting for heteroscedasticity and autocorrelation did not change the results significantly and neither did replacing real R&D expenditure by real R&D stock. The estimation based on the longitudinal sample is in Appendix C.

Explanation of the TFP Gap

In this section, we consider industrial structure, returns to scale and the five exogenous variables, discussed in the section on "Productivity Determinants," to explain the TFP gap and its widening. We first discuss the effect of industrial structure.

The Effect of Industrial Structure

So far, the productivity comparisons are based on firm averages, and the differences in industrial structures between the two countries are ignored. The result is that the estimated results partly reflect differences in industrial structure between the two economies. This is a potential problem, especially for manufacturing, which contains many heterogeneous industries. Table 5 shows both the actual and sample industry shares of gross output in the manufacturing sector. The sample structure was close to the actual structure, although the sample overestimated the shares of some industries such as "chemicals" and "transportation equipment," and underestimated the shares of some industries such as "apparel" and "fabricated metal." There is a slight difference between Canada's industrial structure and that of the United States. According to Table 5, Canada was concentrating more on "lumber and wood," "paper and allied," "primary metal" and "transportation equipment," and less on "chemicals," "rubber and misc. plastics," "non-electrical machinery" and "other manufacturing." To shed light on how industrial structure difference affects productivity comparisons, we conduct an exercise similar to that carried out by Rao and Lemprière (1992*b*). That is, we calculate the TFP gap in manufacturing between the two countries after imposing one country's industrial structure on the other country.[21] To this end, we first derive the productivity gap for each industry and then calculate the weighted sum of the industry productivity gaps for the manufacturing sector as a whole. The weight for each industry is the sample gross output share of this industry in the total manufacturing gross output in Canada or in the United States. As a result, the weighted sum of the industry productivity gaps is the average TFP gap in manufacturing after adjustment of differences in industrial structure.

Table 5
Manufacturing Sector Gross-Output Shares in Canada and the United States

Sector	Percentage of Sector Gross Output to Manufacturing Gross Output[a]											
	Actual						Sample					
	U.S.			Canada			U.S.			Canada		
	85–88	89–92	93–95	85–88	89–92	93–95	85–88	89–92	93–95	85–88	89–92	93–95
Food and kindred products	13.2	13.6	13.1	15.2	15.2	14.3	9.1	9.7	10.0	11.9	9.5	6.8
Textile mill products	2.5	2.4	2.4	2.2	2.0	1.7	0.7	0.8	1.0	0.7	1.0	0.9
Apparel	2.6	2.4	2.3	2.3	2.2	1.8	0.6	0.6	0.8	0.0	0.1	0.2
Lumber and wood	2.7	2.7	3.2	4.9	4.9	6.0	0.8	0.9	1.0	3.8	3.5	5.9
Furniture and fixtures	1.5	1.5	1.5	1.5	1.4	1.3	0.8	0.8	1.0	0.1	0.1	0.2
Paper and allied	4.4	4.6	4.3	7.9	7.6	7.3	4.1	4.5	4.5	11.3	10.3	8.1
Printing, publishing and allied	5.6	5.8	5.5	4.0	4.5	4.0	1.8	1.9	2.0	4.1	6.9	7.7
Chemicals	9.1	10.2	10.0	7.5	7.7	7.5	10.8	11.8	11.9	4.8	4.9	5.0
Petroleum and coal products	5.9	5.5	4.4	6.5	5.6	4.9	20.2	17.6	14.9	10.7	10.1	8.4
Rubber and misc. plastics	3.4	3.7	4.0	2.8	2.9	3.1	1.8	1.9	2.0	0.6	1.1	0.5
Stone, clay and glass	2.5	2.2	2.1	2.6	2.3	1.9	1.2	0.9	0.9	1.3	0.8	0.9
Primary metal	5.1	5.1	4.8	8.2	7.8	7.8	3.2	3.4	3.4	15.6	16.3	14.6
Fabricated metal	6.1	5.7	5.7	5.9	5.6	5.0	1.6	1.6	1.6	0.3	0.7	0.9
Machinery, non-electrical	9.0	8.8	9.5	3.2	3.3	3.3	9.3	10.0	11.4	3.5	3.6	3.6
Electrical machinery	7.7	6.9	8.0	6.0	7.0	7.7	7.8	8.5	9.4	5.6	6.2	8.0
Transportation equipment	13.8	13.1	13.4	17.1	17.8	20.5	21.0	19.7	19.1	24.8	23.9	27.4
Other manufacturing	4.9	5.9	5.6	2.2	2.1	2.0	5.3	5.4	5.1	0.9	1.2	0.9
Total manufacturing	100	100	100	100	100	100	100	100	100	100	100	100

[a] Tobacco and leather sectors are excluded.

Table 6 presents the Canadian manufacturing productivity levels relative to those in the United States after adjustment for differences in industrial structure. For purposes of comparison, we also present Canada's relative productivity levels unadjusted for the different industrial structures, the results based on the two different industrial structures are very similar and they are both higher than the unadjusted results. Although the trend of Canadian productivity movement relative to that of the United States is unchanged after adjustment for the difference in industrial structures, the adjusted productivity gap between Canada and the United States becomes much smaller than the unadjusted gap for all three sub-periods. For instance, in the 1985–88 period Canada lagged behind the United States in TFP level by 22 per cent before adjustment for differences in industrial structure, and by 13 per cent after adjustment to the U.S. industrial structure. The adjusted TFP gap explained 57 per cent of the unadjusted TFP gap. Thus, differences in industrial structure accounted for the remaining 43 per cent of the unadjusted TFP gap.[22] Similarly, the differences in industrial structure accounted for 25 per cent of the TFP gaps in the 1989–92 period, and 27 per cent in the 1993–95 period.

Table 6
Manufacturing Productivity Level in Canada Relative to the United States with and without Adjusting for Differences in Industrial Structure

US=100				
Productivity	**Structure Adjustment**	**85-88**	**89-92**	**93-95**
Gross-output LP	Unadjusted	108.2	97.5	101.4
	Adjusted on Canadian Sample Structure	112.0	101.8	107.9
	Adjusted on U.S. Sample Structure	116.6	104.8	106.3
Value-added LP	Unadjusted	82.1	69.9	75.7
	Adjusted on Canadian Sample Structure	90.6	79.4	85.3
	Adjusted on U.S. Sample Structure	89.5	75.6	81.1
TFP	Unadjusted	78.3	66.1	69.8
	Adjusted on Canadian Sample Structure	88.2	76.2	80.5
	Adjusted on U.S. Sample Structure	87.0	73.2	77.0

Note: The productivity levels are adjusted for differences in industrial structure by attaching equal industry weights in both countries. The weight for each industry equals its sample gross output share of the manufacturing gross output in Canada or the United States, as shown in Table 5.

In view of the fact that the TFP gaps adjusted for industrial structure difference based on both the United States and Canada were lower than the unadjusted gap, we concluded that Canada was concentrating more on industries that were less productive.[23] Industrial structure thus played a role in determining the productivity gap between Canada and the United States. Rao and Lemprière (1992*b*) reach the same conclusion.

After adjustment for industrial structure, the TFP gaps remained at 13 per cent for the first period, 27 per cent for the second and 23 per cent for the third. The widening TFP gap thus remained after adjustment for industrial structure.

Table 7

Productivity Level in Canada Relative to the United States[a]

	U.S. = 100														
	Manufacturing[b]			**Mining**			**TCU[c]**			**Trade**			**Services**		
	85–88	**89–92**	**93–95**	**85–88**	**89–92**	**93–95**	**85–88**	**89–92**	**93–95**	**85–88**	**89–92**	**93–95**	**85–88**	**89–92**	**93–95**
TFP	87.0	73.2	77.0	93.9	87.0	96.3	93.6	81.1	77.0	86.1	71.0	77.4	99.3	79.6	84.0
TFP adj. Q	90.1	83.1	80.0	99.2	102.4	118.4	99.5	86.8	86.0	82.3	74.0	74.6	85.4	75.5	79.2
TFP adj. R	96.4	79.7	83.6	82.9	106.4	109.8	96.3	76.7	76.2	84.6	69.7	76.5	101.4	80.4	81.7
TFP adj. U	86.2	77.4	79.6	89.2	80.6	90.9	91.3	82.9	79.0	81.1	72.6	78.4	96.4	80.4	84.5
TFP adj. S	86.9	72.9	76.8	93.3	87.2	95.6	93.6	81.1	77.0	86.1	71.0	77.4	98.8	79.2	84.2
TFP adj. RES	89.2	75.7	79.2	96.7	90.2	100.2	93.4	80.7	76.6	83.9	68.7	76.2	99.7	80.1	84.4
TFP adj. All	101.5	98.8	92.1	85.1	120.3	131.9	99.7	83.6	87.0	74.3	71.8	73.5	84.6	77.0	77.9

Notes:

[a] The contribution of each factor ($\overline{\alpha}_{z,} \Delta \overline{\ln Z_i}$) is subtracted from equation (6) to calculate the logarithmic difference between Canadian and U.S. firms' TFP adjusted for factor Z_i. The exponent of the resulting number is taken to calculate Canada's TFP level relative to that of the United States after adjusting for factor Z_i.

[b] The TFP levels for manufacturing are Canadian relative TFP levels adjusted to the U.S. industrial structure. In this paper, we adjust manufacturing only for differences in industrial structures between the two countries because of the sector's importance, large TFP gap, higher coverage ratio and more heterogeneous industries.

[c] TCU stands for transportation, communications and utilities.

The Effects of Labour Quality, R&D, Firm Size, Capacity Utilization and Returns to Scale

In order to explain the TFP gap and its widening, we consider five factors as explained in the section on "Empirical Framework." The Canadian relative TFP level after adjustment for each factor is listed in Table 7. The adjustment for manufacturing is based on the TFP level adjusted to the U.S. industrial structure.

First, an adjustment for labour quality raised relative TFP levels in manufacturing, mining and TCU, indicating that Canadian firms' labour quality lagged behind U.S. firms in these three sectors. For manufacturing, an adjustment of labour quality explained 25 per cent of the gap in the 1985–88 period, 41 per cent of the gap in the 1989–92 period and 15 per cent of the gap in the 1993–95 period. For mining, an adjustment for labour quality completely eliminated the TFP gap and put Canadian firms ahead of their U.S. counterparts in the last two periods. For TCU, an adjustment for labour quality explained 92 per cent of the gap in the 1985–88 period, 32 per cent of the gap in the 1989–92 period and 42 per cent of the gap in the 1993–95 period. On the other hand, an adjustment for labour quality did not explain much of the productivity gaps in trade and services.

An adjustment for R&D raised relative TFP levels for all three sub-periods in manufacturing, suggesting that Canadian firms lagged behind their U.S. counterparts in R&D effort — a finding consistent with that of Rao and Lemprière (1992*b*). In fact, differences in R&D accounted for 74 per cent of the TFP gap in manufacturing in the 1985–88 period, 27 per cent of the gap in the 1989–92 period and 31 per cent of the gap in the 1993–95 period. For mining, over the last two sub-periods R&D accounted for all the gaps. For other sectors, an adjustment for R&D did not significantly increase Canadian firms' relative TFP level; this indicates that Canadian firms in these sectors maintained R&D efforts similar to or higher than those of their U.S. counterparts, and that R&D was not responsible for the TFP gap in these sectors.

Capacity utilization accounted for some of the manufacturing TFP gap in the last two sub-periods. It accounted for 18 per cent of the gap in the 1989–92 period, and 13 per cent of the gap in the 1993–95 period. Adjustment for differences in capacity utilization failed to raise significantly the relative TFP levels for other sectors, indicating that differences in capacity utilization were not responsible for the TFP gap in these sectors.

An adjustment for firm size left virtually unchanged the relative TFP levels; thus firm size was not responsible for the TFP gap in these sectors.

An adjustment for returns to scale explained a small portion of the TFP gap in mining. In any case, our estimates in Table 3 indicate that all five sectors were operating fairly close to constant returns to scale.

The combined effects of all five factors accounted for the entire TFP gap in manufacturing in the 1985–88 period, 96 per cent of the gap in the 1989–92 period, and 69 per cent of the gap in the 1993–95 period. In addition, these factors accounted for 6 per cent of the widening TFP gap in manufacturing between 1985–88 and 1993–95. After adjustment for differences in the five factors, Canada's TFP position relative to that of the United States in mining was reversed in the 1989-95 period and Canada's TFP level increased substantially over time. Thus these factors were responsible for the TFP gap in mining in Canada in the 1989-95 period. For TCU, an adjustment for all these factors reduced its TFP gap; the factors were responsible for 95 per cent of the TFP gap in the 1985–88 period, 14 per cent of the gap in the 1989–92 period, and 47 per cent of the gap in the 1993–95 period. The five factors were also responsible for 23 per cent of the widening TFP gap between 1985–88 and 1993–95 in this sector. In trade and services, adjustments for differences in the five factors actually lowered relative TFP levels, indicating that the factors considered were in Canada's favour and were not responsible for the existence of a TFP gap in these sectors. But the factors were responsible for 91 per cent of the widening TFP gap in trade, and 56 per cent of the widening gap in services between 1985–88 and 1993–95.

CONCLUSIONS AND POLICY IMPLICATIONS

Measured by value-added labour productivity or TFP, Canadian firms' productivity performance deteriorated in the 1993–95 period compared to the 1985–88 period for all sectors except mining, and Canadian firms were less productive than their U.S. counterparts in all five broad sectors in the 1993–95 period. Capital intensity was relatively stable in Canada compared to the United States. Lower TFP and its deterioration were responsible for the poor value added–based labour productivity performance in Canada.

Important factors in explaining the TFP gap between Canadian and U.S. firms in these sectors were labour quality, R&D, capacity utilization and an unfavorable industrial structure in manufacturing; labour quality, R&D and returns to scale in mining; and R&D in TCU. However, the same factors were not responsible for the TFP gap in trade and services. Labour quality, R&D, capacity utilization, firm size and returns to scale together were responsible for the widening TFP gap between 1985–88 and 1993–95 in all sectors except mining.

This paper shows that R&D and labour quality are important in reducing the productivity gap between Canadian and U.S. firms. Given that Canada is a small, open economy with a high degree of foreign ownership, especially in the manufacturing sector, it may be difficult to raise formal R&D in Canada. However, lower taxes and other means to retain and attract top researchers will certainly help to raise R&D activity in Canada. But being a small, open economy, we cannot hope to raise the level of R&D on all fronts. Instead, Canada needs to find its niche in R&D activity through specialization. That is, specialization in R&D should coincide with our comparative advantages. Labour quality is another important element to reduce the productivity gap. Education and continuous learning should form the basis of the government's policy agenda. Moreover, the tax structure should minimize distortions so that learners and achievers would be rewarded properly. There are other possible factors that have not been investigated in this study. Future research may need to consider the effects of competition, free trade and taxes on the Canada–U.S. productivity gap.

APPENDIX A
THE OBSERVATION-OVERWHELMING EFFECT

Estimation of the parameters in equation (2) is essential to analyse the productivity gap. Some explanation is needed. It should be noted that when using the TFP measure, not only must all slopes be constant over the sample period but they must be the same across the two countries. Unfortunately, our sample evidence indicates that the estimated slopes between the two countries are not the same. Therefore, if the average slopes between the two countries are estimated by pooling both countries' samples together, the estimated results will be biased against Canada since the U.S. sample size is much larger than that of Canada. In other words, as the U.S. sample size increases, the estimation will give more weight to the United States. We call this phenomenon the observation-overwhelming effect. To confirm this conjecture, we conduct Monte Carlo experiments for manufacturing by randomly choosing a different number of U.S. observations without changing the number of Canadian observations in estimation. The results presented in Table A1 are based on repeating the same process 500 times. The first estimated TFP level in Canada relative to the United States is based on the same sample size for the United States and Canada. We then increase the sample size of the United States in experiments 2 and 3. The results show that the value-added labour productivity and TFP gap between Canada and the United States decreases with the increase in the U.S. sample size.[24]

In Table A1, we also listed the results by estimating the labour productivity function using a sample pooling all the U.S. and Canadian observations together, as shown in the row named "Approach 1." The "Approach 2" row presents the results based on the technique used in our paper; that is, we estimate each country independently using its own observations, and then we use the average of the estimates to conduct productivity comparisons.

We arrive at two main conclusions from our Monte Carlo experiments. First, the standard deviation is very small for all experiments, implying that the sample sizes are large enough to produce stable estimation. Second, the means of value added–based labour productivity and TFP increase with the U.S. sample size. This suggests that the observation-overwhelming effect has distorted the estimation and needs to be corrected for in the estimation procedure.

An obvious way of eliminating the observation-overwhelming effect is to use an equal number of observations from the two countries in estimating equation (2). However, this results in efficiency loss since some valuable information is not used. A more efficient way is to estimate the coefficients for each country separately and to take an average of the estimated coefficients. The two methods, however, generate very similar results, as can be seen by comparing the first Monte Carlo experiment results in Table A1 with the results presented in the "Approach 2" row in the same table.

Table A1
Canada's Productivity Level in Manufacturing:
The Monte Carlo Experiments
(mean and standard deviation, U.S. = 100)

Productivity	85–88		89–92		93–95	
Monte Carlo 1 (U.S. observations 2 603; Can. observations 2 603; repeating times 500)						
Productivity	**85–88**		**89–92**		**93–95**	
Gross output LP	116	(2.6)	97	(2.1)	99	(2.7)
Value-added LP	85	(1.5)	67	(1.3)	75	(1.7)
TFP	79	(1.4)	63	(1.2)	69	(1.5)
Monte Carlo 2 (U.S. observations 7 809; Can. observations 2 603; repeating times 500)						
Productivity	**85–88**		**89–92**		**93–95**	
Gross output LP	116	(1.4)	97	(1.1)	99	(1.3)
Value-added LP	88	(0.9)	70	(0.7)	78	(0.9)
TFP	83	(0.8)	67	(0.6)	72	(0.9)
Monte Carlo 3 (U.S. observations 13 015; Can. observations 2 603; repeating times 500)						
Productivity	**85–88**		**89–92**		**93–95**	
Gross output LP	116	(0.8)	97	(0.6)	99	(0.7)
Value-added LP	89	(0.5)	71	(0.5)	79	(0.5)
TFP	84	(0.5)	68	(0.4)	73	(0.5)
Approach 1: (U.S. observations 21 245; Can. observations 2 603)						
Productivity	**85–88**		**89–92**		**93–95**	
Gross output LP	116		97		99	
Value-added LP	90		72		79	
TFP	85		68		73	
Approach 2: (U.S. observations 21 245; Can. observations 2 603)						
Productivity	**85–88**		**89–92**		**93–95**	
Gross output LP	116		97		99	
Value-added LP	84		66		74	
TFP	79		63		69	

Notes:
Standard deviation is in parentheses.
All productivity is calculated using a simple firm average; that is, each firm is equally weighted. Two different methods are employed to estimate the slope coefficients used to calculate each firm's productivity. For all Monte Carlo experiments and Approach 1, we assume that the slope coefficients of the two countries are the same and estimate them by simply pooling both countries' samples together. For Approach 2, we estimate the coefficients for each country independently and then use the simple averages of their estimates for both countries.

APPENDIX B
DATA DESCRIPTION

Table B1
List of Variables and Parameters Used

Variable	Description	Source
S	Net sales (current $)	Compustat / Compact Disclosure
I	Inventory change (current $)	Compustat / Compact Disclosure Industry average (*I/S*) multiplied by firm's *S* for missing firm data
YN	Gross output (current $)	$= S - I$
KN	Net PPE (property, plant and equipment, current $)	Compustat / Compact Disclosure[1]
CG	Cost of goods sold (current $)	Compustat / Compact Disclosure Industry data used for missing firm data
L	Total number of employees	Compustat / Compact Disclosure[2]
WLN	Total labour compensation (current $)	Compustat / Compact Disclosure Industry average (*WLN/L*) multiplied by firm's *L* for missing firm data
WN	Labour compensation per worker (current $)	$= WLN/L$
MN	Intermediate input, including energy and material	$= CG - WLN$
RD	Total expenditure on R&D	Compustat / Compact Disclosure Industry average (*RD/S*) multiplied by firm's *S* for missing firm data
PY	Gross output deflator (26 industries)	Canada: CANSIM[3] United States: U.S. Department of Commerce[4]
PK	Capital deflator (26 industries)	Canada: Statistics Canada United States: Survey of Current Bussiness (May 1997)
PM	Intermediate goods deflator (26 industries)	Canada: Statistics Canada's KLEMS data base[5] United States: Jorgenson's KLEM data base[6]
Y	Gross output (real $)	$= YN/PY$
K	Capital stock (real $)	$= KN/PK$
M	Intermediate input (real $)	$= MN/PM$
Q	Labour quality	$= WN/PY$
θ	Value-added labour share	StatCan's KLEMS and Jorgenson's KLEM
R	R&D factor	$= RD / L^{\theta} K^{1-\theta}$
U	Capacity utilization	Canada: CANSIM[7] United States: *Business Statistics of the United States* (1996 edition)

Table B1 (cont'd)

Variable	Description	Source
g	R&D expenditure average growth rate over 1973–85	OECD ANBERD data base; CANSIM; NBER data base
RS	R&D stocks	$RS_{85} = RN_{85}/(\delta + g)$; $RS_t = (1-\delta)RS_{t-1} + RD_t$
P_1	Period dummy for 1985–88	
P_2	Period dummy for 1989–92	
P_3	Period dummy for 1993–95	
S_1	Size dummy for firms with capital of less than $30 million	
S_2	Size dummy for firms with capital of over $30 million but less than $150 million	
S_3	Size dummy for firms with capital of over $150 million	
PPPs	Purchasing power parities	Pilat (1996*b*), OECD (1993)

Notes :

1 Net PPE (property, plant and equipment) is used since it depreciates old capital to allow for technological obsolescence while gross PPE, which does not depreciate old capital, may exaggerate capital stock levels of firms.

2 There are no data on hours worked. However, for the purposes of our study, the use of the number of employees is not likely to affect the results significantly since hours worked per employed person in Canada and the United States are almost the same; see Dougherty (1991), p. 8.12.

3 The gross output deflator is a producer price index at the 26-industry level. For Canada, the source for all industries for 1985–92 and for manufacturing for 1993–95 is CANSIM. Data for non-manufacturing sectors for 1993–95 are not available. They are approximated by extending the figures of these sectors in 1992 in accordance with the change in the implicit price index for GDP.

4 For the United States, the source for all industries for 1985–94 is the U.S. Department of Commerce. Data for 1995 are not available. They are approximated by extending the figures in 1994 in accordance with the growth rates of industrial production of all industries, taken from *Business Statistics of the United States* (1996 edition).

5 The intermediate goods deflator is a producer price index at the 26-industry level. For Canada for 1985–92, it is constructed from the Statistics Canada's KLEMS data base. For the remaining years, it is approximated by extending the figures in 1992 in accordance with the growth rates of output price.

6 For the United States for 1985–91, the intermediate goods deflator is constructed from the Input-Output Data Base by Dale W. Jorgenson. For the remaining years, it is approximated by extending the figures in 1991 in accordance with the growth rates of output price.

7 Capacity utilization is at the 5-industry level. For both Canada and the United States, data are only available for manufacturing and mining. For other sectors, capacity utilization for total industry is used.

APPENDIX C
THE ESTIMATION BASED ON A LONGITUDINAL SAMPLE

The estimated results based on the unbalanced data set may reflect influences from heteroscedasticity, autocorrelation or mispresentation of the R&D variable. In order to assess the impacts of these possible influences on the estimated results, we estimate our model using manufacturing's longitudinal data extracted from the unbalanced sample. We carry out this exercise only for manufacturing since we do not have enough observations for other sectors. The longitudinal data set for manufacturing contains 59 Canadian and 1 115 U.S. manufacturing firms from 1985 to 1995. The log-likelihood statistical tests (not reported) show significant heteroscedasticity and autocorrelation in the longitudinal sample.

The relative productivity levels under various assumptions are reported in Table C1. According to this table, the TFP gaps based on the longitudinal sample under the assumptions of homoscedasticity and non-autocorrelation (column *i* of each period) were smaller than those based on the unbalanced sample. The departure was due mainly to the different industrial structures of the two samples.

The empirical results based on the longitudinal data adjusted for heteroscedasticity and autocorrelation (in column *ii* of each period) were not significantly different from those under the assumptions of homoscedasticity and non-autocorrelation.

So far our empirical results are based on the variable *R* constructed as the ratio of R&D expenditures to weighted capital and labour. We also consider a more commonly used R&D variable, the ratio of R&D stock to weighted capital and labour. The estimated results using the new R&D variable are presented in column *iii* of each period in Table C1.[25] Again it is clear that this consideration has no significant impact on our results.

Table C1
Canada's Productivity Level Relative to that of the United States in Manufacturing, with Longitudinal Data

	U.S. = 100											
Period	**85–88**				**89–92**				**93–95**			
Canadian productivity level	**Whole data**	**Longitudinal**			**Whole data**	**Longitudinal**			**Whole data**	**Longitudinal**		
		(i)	(ii)	(iii)		(i)	(ii)	(iii)		(i)	(ii)	(iii)
Gross output LP	108.2	108.0	108.0	108.0	97.5	103.2	103.2	103.2	101.4	112.4	112.4	112.4
Value-added LP	82.1	87.8	91.6	92.4	69.9	79.0	83.4	84.4	75.7	86.0	90.7	91.8
TFP	78.3	83.3	85.6	85.0	66.1	73.6	76.2	75.4	69.8	79.1	81.8	80.7

Notes:
In case (i), R&D is introduced in the form of R&D expenditures, weighted by the average values of capital and labour, as before. R&D expenditures were not weighted by Y as commonly used since Y is assumed to be endogenous.
In case (ii), case (i) is adjusted for heteroscedasticity and autocorrelation.
In case (iii), R&D expenditures in case (ii) are replaced by R&D stocks.

NOTES

1 A study by Dougherty and Jorgenson (1997) is an exception. The authors find that Canada's productivity level was slightly higher than that of the United States in 1989. Their measurement of productivity differs from that of others in that they adjust for differences in capital and labour quality.

2 They did not have the data to calculate TFP for non-manufacturing industries in the United States.

3 The Cobb-Douglas production function is assumed since it allows us to clearly define TFP as the ratio of output to a weighted sum of capital, labour and intermediate input. Because of its simplicity, this functional form has been commonly used for productivity analysis in the literature — for instance, by Bernard and Jones (1996*a,b*), Ehrlich et al. (1994), Griliches (1986) and Wolff (1991). Furthermore, a TFP gap derived from a translog production function also takes a Cobb-Douglas form, as in equation (3); see Jorgenson (1995).

4 In this paper, the efficiency coefficient, A, is assumed to be a function of several exogenous variables, Z, discussed in the next section.

5 There are 19 industries in manufacturing, 4 in mining, 3 in TCU, 2 in trade and 1 industry in services.

6 As an alternative measure to TFP, Bernard and Jones (1996*a*) discuss the total technological productivity (TTP), allowing output elasticities to differ between two countries. We attempt TTP measures with inputs based on Canadian or U.S. firms. The average TTP gaps are very different. This is not surprising since there are several problems associated with the measure. First, the measurement of the TTP gap is sensitive to the choice of K, L and M. Should Canada's or the United State's K, L, M or the two countries' averages be used? No economic theory tells us how K, L and M should be chosen. Second, it is impossible to carry out a decomposition exercise to assess the contribution of each factor to the TTP measurement since the calculated contribution is sensitive to the units of measurement for each factor. Finally, the measurement of the TTP gap is sensitive to the level of aggregation. For instance, inputs at the firm level are much smaller than inputs at the economy-wide level, resulting in a very different measurement of the gap.

7 See Diewert (1976), Diewert and Nakamura (1993), and Good, Nadiri and Sickles (1996) for the index number approach to productivity measurement.

8 We also implicitly assume that the elasticities are constant over the sample period so that comparisons can be made over time.

9 TFP is generally defined as A, the efficiency coefficient in equation (1). In this paper, it is defined as A plus the returns to scale component. The departure is solely for the sake of simplicity and will not affect our results since the returns to scale component was not an important factor in determining productivity gaps between the two countries.

10 The 26 industries are composed of 19 manufacturing industries (corresponding to the Statistics Canada two-digit classification) plus mining, transportation, communications, utilities, wholesale trade, retail trade, and services industries. Agriculture, fishing, forestry and construction are excluded because of inadequate observations; finance, insurance and real estate are excluded because their behavior is difficult to predict; in addition, the measurement of their variables is subject to error since they do not produce tangible output. See Maclean (1997).

11 Because of the lack of firm-specific deflators, this methodology is often used in empirical studies based on firm data. See, for example, Griliches and Mairesse (1991), Hall and Mairesse (1995) and Mairesse and Hall (1996).

12 Of the observations, 4 per cent are missing data for intermediate input, 69 per cent for labour-related cost, and 28 per cent for R&D.

13 One major problem with this proxy is the causality between the productivity and labour compensation. Some people may argue that more productive firms pay higher labour compensation. This is possible. Unfortunately, we do not have better alternatives. Jensen, McGuckin and Stiroh (1998) also use wages as a proxy for the quality of the work force.

14 Alternatively, we experiment with real R&D stock per labour with longitudinal data. The results are discussed at the end of the next section.

15 In our estimation, the average value of the 1990 value-added labour shares of Canada and the United States is used.

16 Sales or the number of employees can also be used to measure firm size. However, different choices of these variables do not make significant differences to our results.

17 The reported results assume homoscedasticity. Different specifications of heteroscedasticity are considered but they do not generate significantly different results. These results, therefore, are not reported.

18 The size effect should not be confused with returns to scale. Small firms may maintain a production function characterized by increasing returns to scale.

19 Canadian relative productivity levels fell in the 1989–92 period, mainly because of the fall in Canadian productivity levels in this period — the result of a recession that was more severe in Canada than in the United States.

20 The longitudinal data set contains 59 Canadian and 1,115 U.S. manufacturing firms for the period from 1985 to 1995.

21 We carry out this exercise only for manufacturing because of its importance, large productivity gap and high coverage ratio.

22 For a decomposition of the unadjusted TFP gap into a structure-adjusted TFP gap and the gap caused by the differences in industrial structure, see Tang and Rao (1998).

23 The sufficient condition for this statement is that both adjusted TFP gaps based on the two countries' industrial structures had to be lower than the unadjusted TFP gap because of different industry TFP levels between the two countries.

24 The gross output–based labour productivity gap does not change as the U.S. sample size increases since it is determined by $\Delta\overline{\ln(Y/L)} = \overline{\ln(Y/L)}^{CAN} - \overline{\ln(Y/L)}^{US}$, which is not affected by the estimated parameters.

25 R&D stock is estimated by the equation $RS_t = (1-\delta)RS_{t-1} + RD_t$, where δ and RD_t denote the depreciation rate and R&D expenditure respectively in year *t*. We assume $\delta = 0.1$, which is frequently used in literature; see, e.g., Gera, Gu and Lee (1998*b*). The R&D stock in the initial year (1985) is estimated by the equation $RS_{85} = RD_{85}/(\delta + g)$, where *g* is the average growth rate of R&D expenditure over the period 1973–85, based on the OECD's Analytical Database of Business Enterprise R&D (ANBERD). The R&D expenditures are deflated by gross output deflator constructed from CANSIM for Canada and from the National Bureau of Economic Research (NBER) productivity data base for the United States.

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